CoA Memo. No. 102

The College of Aeronautics, Cranfield

Department of Production and Industrial Administration

The numerical evaluation of
the grinding process and the
basic mechanics of grinding
wheel wear.

by

John Purcell, C.Eng., A.M.I.Prod.E., A.M.I.Plant.E.

Contents

Summary
Introduction

Section I

(a) The Numerical evaluation of the grinding process

(b) The two methods of measuring the approach angle alpha on the leading edge of the grinding wheel.

(c) Calculating

E = The effective depth of cut per grit
L = The grit arc of contact length (undeformed chip length)

Alpha = The approach angle

Section 2

The interpretation of grinding wheel wear.

a. The significance of the proportions of the approach angle

b. Interpretation of the limiting factors of grinding wheel performance.

c. To compare the efficiency of different coolants

d. To compare the machinability of different materials

e. To predict the useful life of the grinding wheel face between redressing operations when used under conditions different to the test conditions.

f. To calculate the performance of a grinding wheel which is of different diameter to the one used in the evaluation test.

Conclusions
Test sheets
figures

Introduction

During the production process development for the manufacture of an experimental supersonic aircraft , an unusual and difficult grinding problem was encountered.

Arising from the xperimental work carried out to solve this problem, a method of numerically evaluating the efficiency of grinding wheels and coolants, was developed. This evaluation is based on the fact that under constant and limited grit load conditions which can be set up in a surface grinding operation, the edge of the grinding wheel which makes initial contact with the workpiece breaks down and forms an approach angle as shown in Fig. 1. Once this angle is established, its dimensions remain almost constant, and with continued use of the wheel the angle recedes across the face of the wheel. It is the recognition of the variables which control the dimensions of this approach angle (alpha) together with the rate at which it recedes across the wheel face, and the amount of work done at each increment of recession, on which the numerical evaluation of the efficiency of the grinding wheel and the causes of the limitations are based.

A description of the methods used for determining the characteristics of grinding wheels and coolants are included together with the calculations which are necessary when the data obtained from tests carried out on the surface grinding machine are to be interpreted and applied to the cylinder grinding internal grinding or form grinding processes.

1. Numerical evaluation of the grinding process

The method of evaluation is centred upon the recognition of the variables which control the proportions of the triangle containing alpha, the leading edge approach angle (Fig 1). The surface grinding process is considered.

(a) The two methods of measuring the approach angle on the leading edge of the wheel

The measurement of the approach angle is achieved in two ways.

1. By smearing a thin layer of engineers marking blue on the surface of the workpiece and bringing the grinding wheel down just to remove this along the path the wheel makes when the table is longitudinally traversed with no cross feed. Fig 2 shows this method. From Fig 2 it is seen that, using a pair of sharp dividers, the width of the wheel path can be measured to less than 0.010 ins., which is less than one grit width in a 60 grit wheel.

This initial measurement is made before the test commences and gives the width of the redressed wheel face. It has been found that, due to the cutting forces being applied to the hypotenuse of the approach angle alpha, the wheel is deflected in a way which lifts the dressed wheel face and trailing edge of the wheel from contact with the workpiece. Only the grits on alpha and those at the apex are responsible for metal removal.

The above observations suggest that the grinding wheel suffers no loss in diameter, and that if the cutting forces are removed, the wheel face will return to the no load position in which it was first redressed. After work has been done, any loss from the leading edge of the wheel can be measured by repeating the marking blue technique described above.

The wheel face loss is found by subtracting the second measurement from that taken before the wheel was used. This difference (given the symbol B in Fig 1) is the length of the base of the approach angle alpha, a further side being D, the applied depth of cut. As the angle B.D. is a right angled triangle, the remaining values may be calculated.

Note:- When the leading edge of the grinding wheel cross traverses over the side of the workpiece, the cutting forces are removed, allowing the dressed wheel face to return to normal no load position. Close observation of the surface of a workpiece which has been surface ground will show evidence of this wheel return. A very light plunge cut mark will be left down the edge of the workpiece surface, equal to the unworn width of the wheel face. This can be used to check the blue method of measurement.

2. The second method of measurement of alpha is to stop the machine table during a cutting pass, and make a trace of the form left by the grinding wheel face on the surface of the workpiece. The Taylor, Taylor Hobson machine (supplied by Alfred Herbert Coventry) is ideal for this purpose. Fig 3 is a photocopy of a Talisurf trace. This shows alpha proportions and enables the chip size calculations to be checked as shown on the tracing using the symbols as given in Fig 1.

The basic calculations for the chip shown on the trace (Fig 3) would be as follows.

(b) Calculations of E the effective depth of cut per grit, L the chip length, α the approach angle

$$E = F \tan alpha = F \times \frac{D}{B} \quad \text{i.e. } E = 0.042 \times \frac{0.001}{0.140} \text{ ins.}$$

$$E = 0.0003 \text{ ins.}$$

This is the self adjusted maximum depth of cut per grit.

$$L \text{ (chip length)} = \sqrt{E \times \text{Wheel diameter}} = \sqrt{0.0003 \times 7 \text{ ins}} = 0.046 \text{ ins.}$$

L = length of chip = L = 0.046 ins.

$$\text{Tan Alpha} = \frac{D}{B} = \frac{0.001}{0.042} = 0^{\circ}\ 24'$$

M the maximum depth of grit penetration is not calculated as it is influenced by the radial distance the active grits are apart. This varies, E and L are simple values to calculate and are adequate to interpret the significance of alpha proportions and on which to express grinding wheel efficiency.

2. Intepretation of grinding wheel wear

(a) The significance of the proportions of alpha. By variation of the variables which control the proportions of alpha, one is able

1. To differentiate between the grit failure due to its inability to penetrate the workpiece, and grit loss due to lack of porosity in the wheel.

2. To compare coolants in terms of grinding wheel efficiency.

3. To compare the machinability characteristics of various materials in terms of grinding wheel efficiency.

4. To predict the life of a grinding wheel when used at metal removal rates other than that at which the wheel was tested.

5. To predict the performance of a wheel which is up to 100% larger or 25% of the diameter of the tested wheel.

Examples of the above are presented.

(b) To diagnose the cause of grinding wheel face failure or limitation This can be caused by three things

(1) The inability of the grit to withstand penetration pressure.

(2) The lack of adequate chip space (porosity)

(3) The weakness of the bonding material

Test result Sheets No. 1, 1A

These test sheets show the results of a standard wheel selection test for a grinding wheel to specification UN1, W.A. 60 IV

The calculations made are:

B (measured)	= 0.070 ins.	D (applied)	= 0.001 ins.
F applied	= 0.042 ins.	L (calculated)	= 0.0646 ins.
E calculated	= 0.0006 ins.		= 0^{o} 49'

Symbols are as in Fig 1.

A (measured) = 0.015 inches per 0.05 cubic inches of metal removed.

Similar tests for grinding wheel specification UN1. W.A. 60 JV were made with the following results.

Test Results Sheet No. 2 and 2A

B = 0.070 ins.	D = 0.001 ins
F = 0.042 ins.	E = 0.0006 ins
L = 0.0646 ins.	

A = 0.0116 ins per 0.05 cubic ins. of metal removed.

It will be noted that the chip sections in the above two cases are identical. Only A, the amount of wear on the wheel (progression of alpha across the wheel face), has changed. Test results sheets No. 2. 3, 3A and 2A, 4, 4A show similar change in A for two other test sheets to a different specification. The change is shown to be 0.016 ins. and 0.012 ins. for similar metal removal (0.05 cu. ins).

Note that E is changed with specification change in the case of UN1. W.A. 60 I AND J V, when E = 0.0006 ins, while CARBORUNDUM 7.A.60.I5.VF8 and the J grade in this specification produced E = 0.0004 inches. This is a comparison of their relative efficiencies, as only the wheel specification was the subject of test variation

If the bond strength of a wheel is too strong, excessive wear will be allowed to occur on the grits causing greater grit face/work surface contact. This will result in elevated temperatures and wheel loading. A weak wheel bond will allow excessive grit loss before any work is done. This is recognised by loss of wheel form and a very clean unused appearance of the wheel face.

(c) To compare coolant efficiency. Tests results sheet No. 5, 5A, 6 and 6A. These results are records of tests carried out with all conditions being similar to those reported on previous results sheets except that the grinding wheel specification is changed to CARBORUNDUM A.54. J5. V30. This wheel is first used with oil coolant as in all previous tests and then, after de-greasing, the wheel was filled with sulphur and used dry The values of E are lower than for previous wheels which, shows that this 54 Grit wheel is less efficient. The precise reason is not apparent from this single test and should be found by varying bond strength and porosity.

The values for E for the two coolants are equal at 0.0003 ins It is A which reflects coolant/lubricant efficiency. A coolant does not change the porosity, nor is the time during which the alpha angle is developing, long enough to show any change in the rate of wear on the grits. When alpha is formed the grits situated upon the hypotenuse stay in situ and continue to cut chips at each revolution of the grinding wheel until sufficient wear has occurred on the cutting points to increase the forces to a value exceeding that which the bond of the grit can withstand. The bonds then break and the worn grits are displaced from the wheel, thus exposing another grit row to continue the task. Test result sheet No. 7 records the results of wear measurements made for wheel specification UN1. W.A. 60 I.V. (See also calculations made on test results sheet No. 1.) From Sheet No. 7 the cyclic readjustment of alpha across the wheel is evident and it is the volume of metal which is removed between each readjustment that is influenced by the efficiency of the coolant.

A in the Test on cutting oil is equal to 0.010 ins. for each 0.05 cubic ins. of metal removed. The improvement when using the sulphurised wheel, where A = 0.007 ins. per 0.05 cu. ins. of metal removed, is a direct measure of the efficiency of these two methods of cooling/lubricating.

(d) To compare workpiece machinability. The comparative machinability of materials. (Fig 4) shows schematically the chip size when the workpiece material is changed, oth.r conditions remaining constant. The workpiece materials are:-

(1) S.107 Case hardened gear steel

This gave a chip section E = 0.000236 and L = 0.0268 ins.

(2) A through hardened bearing steel E = 0.000373 and L = 0.03136 ins

(3) Hardened gauge plate E = 0.00066 and L = 0.0681 ins. (straight carbon steel)

All are equal in hardness 700 V.P.N.

It is seen that as the severity of machinability was reduced the chip section became larger and it can be assumed that if the porosity of the wheel could accommodate a gauge plate chip of 0.0006 ins., it could equally well have accommodated such a chip from the S.107 steel. Hence it must be that the limitation in the case of S.107 is due to the grit not being capable of cutting such a chip and that wheel porosity is more than adequate. M is the limiting factor, this is the maximum penetration during the formation of the chips.

This method of differentiating between lack of porosity and grit limitation supplements wheel grade changes and is to be preferred to changing wheel specification. The chip sizes can be used as a machinability index, with reference to grinding.

(e) To predict the life per redress of a wheelface when used under other than the tested conditions.

From test results sheet No. 7 it will be seen that the leading edge of the wheel suffers a loss of 0.070 inches by the time 29 sq. ins. of surface area has been ground. This area is at 0.001 depth of cut, hence 0.029 cubic inches of metal have been removed. This is the point where alpha is stable and the wear is now arrested until 150 sq. ins. have been ground. Here, 0.025 ins. is lost from the wheel width. 310 sq. ins. sees the next adjustment when 0.020 ins is lost. Further adjustments occur at 436 sq. ins., 562 sq. ins, 684 sq. ins., 720 sq. ins and 836 sq. ins. The loss on the wheel averages out at 0.020 inches per readjustment and for each of these losses, approximately 130 sq. inches of surface is ground, or 0.130 cubic inches at 0.001 depth of cut. From these figures the expected life of the wheel face can be calculated thus.

Wheel face width before test (test result sheet No. 7) = 0.780 ins. loss on wheel face to stabilise alpha = 0.070 ins. = B length average loss per readjustment = 0.020 inches metal removed per above loss = 0.130 cubic inches. When the alpha angle nears the trailing edge of the wheel there is a lack of support for the grits, and failure occurs. It is necessary to allow twice B

(b) <u>To calculate the performance of a grinding wheel which is larger than the tested wheel</u>

It is possible to predict the performance of a grinding wheel made to a similar specification as the test wheel but larger or smaller in diameter.

The size of the approach angle controlling the chip size is the criterion and the chip size must remain sensibly unchanged. Therefore, if the wheel diameter changes (increases) alpha must change to reduce chip length and M back to the original maximum and this is a direct geometrical relationship.

$$L = \sqrt{E \times \text{Wheel diameter}}$$

therefore $L^2 = E \times \text{wheel diameter}$

and $\frac{L}{E}$ = wheel diameter

or $\frac{L}{\text{wheel dia.}} = E$

In the test condition results sheet No. 2

$B = 0.070$ $\quad L = 0.0646$
$E = 0.0006$ $\quad A = 0.0116$

Wheel diameter was 7 inches
Applying these values to the above equations

$$L = \sqrt{E \times \text{Wheel dia.}} = \sqrt{.0006 \times 7} = 0.0656 \text{ ins.}$$

and $L^2 = 0.0006 \times 7$

and $\frac{L^2}{0.0006} = 7 \qquad \frac{L^2}{7} = 0.0006$

length for this. Therefore,

$$\frac{\text{Wheel width} - 3\text{ B (alpha lengths)}}{\text{Average Loss of Wheel Face per Adj. on Alpha per adjustment on each readjustment}} \times \text{Vol. of metal removed} + \text{Vol. removed to form B.}$$

$$= \frac{0.029 + (0.780 - 3\ (0.07)) \times 0.130}{.02} = \text{life in cubic inches of metal removed.}$$

TOTAL LIFE = 3.7 cubic inches per redress
+ (0.029 being the metal removed to form alpha initially)

The angle alpha controls the grit task or chip size to a near maximum, and if any of the conditions change, then alpha changes to reproduce the former chip size.

Fig 5. shows that alpha does not change if the depth of cut is varied, the additional grits being brought into use in radial depth. The proportion of the approach angle sides change, the angle alpha remaining constant. A change in the cross feed rate will change alpha (Fig 6). This is due to the additional grits being presented on the hypotenuse length of the approach angle. After the readjustment of alpha, E is similar to that prevailing before the change, hence the chip is idential. When the surface speed of the table is changed, alpha must change to present the grit task uneffected M is the criterion. Fig 7 shows that E changes when alpha is changed. If F (the cross feed remains constant) M is controlled by E, the depth of cut per grit and V.T. the table speed) see Fig 1 for Symbols) and at the decreased depth of cut E. Fig 7 (b), in the time T for a grit to rotate the reduced arc of contact length, the table travelling at increased speed V will produce a depth of penetration M equal to that previous to the table speed change and L the chip length will also be approximately constant.

The amount of wheel face lost to form the approach angle alpha will influence wheel face life.

BUT WHEN ALPHA IS STABLE, THE LOSS ON THE REMAINING WHEEL FACE WILL BE CONSTANT AND NOT INFLUENCED BY THE METAL REMOVAL RATE.

This statement is proved by the fact that when alpha is stable the grit task is constant. Therefore rate of wear will be constant.

therefore if we increase the wheel diameter to 14 inches we must reduce E to maintain chip size. Thus

$$\frac{L^2}{7} = E \quad \frac{L^2}{7} \times \frac{7}{14} = \text{New E} \qquad \frac{L^2}{14} = \text{New E}$$

$$= \frac{0.0646^2}{14} = 0.0002981$$

The new E must be 0.0003 inches and this will be produced by B length increasing. The opposite action occurs when the diameter of the grinding wheel is reduced in size.

It must be remembered that the life of the grit, when alpha is stable, will be proportional to the diameter ratios. An example is the change from 7 ins. to 14 inches diameter, - the grit life would be doubled, that is A, readjustment volume removed ratio would be twice the original.

The application of the basic test results to cylindrical internal and form grinding is being proved by practical tests.

Fig 8 shows this basic application schematically.

Test Results Sheet No. 7.

Grinding wheel selection and wear test

Conditions:- The machine. Jones and Shipman 540 surface grinder

Coolant Manchester Oil Refinery Dolphin No. 1

Delivered at 5 pints per minute

Grinding Wheel Specification U.N.1. W.A. 60 I.V.

Size of wheel 7" dia. 1" thick, $1\frac{1}{4}$" bore

Workpiece material

S.107 Case Carbonised. Heat treated .700 V.P.N.

Metal removal rate:-

Depth of cut D = 0.001 ins. Cross feed F = 0.042 ins/table stroke

Table speed = 62.5 ft per minute = V.

Surface area ground sq. ins.	wheel face width ins.	wheel face loss ins.	V.P.N.	Surface finish C.L.A. micro ins.
Start	0.780	-	759	-
19	0.745	0.035	-	-
29	0.715	0.030	-	10
79	"	none	-	5
114	"	"	770	5
150	0.690	0.025	-	-
238	"	none	-	-
256	"	"	-	-
292	"	"	715	5
310	0.670	0.020	-	-
336	"	none	-	-
400	"	"	-	5
436	0.650	0.020	730	-
490	"	none	-	-
526	"	"	-	-
562	0.640	0.010	-	5
616	"	none	-	-
657	"	"	-	-
684	0.625	0.015	-	-
720	0.605	0.020	720	5
765	"	none	-	-
800	"	"	-	-
836	0.590	0.015	725	5

End of test

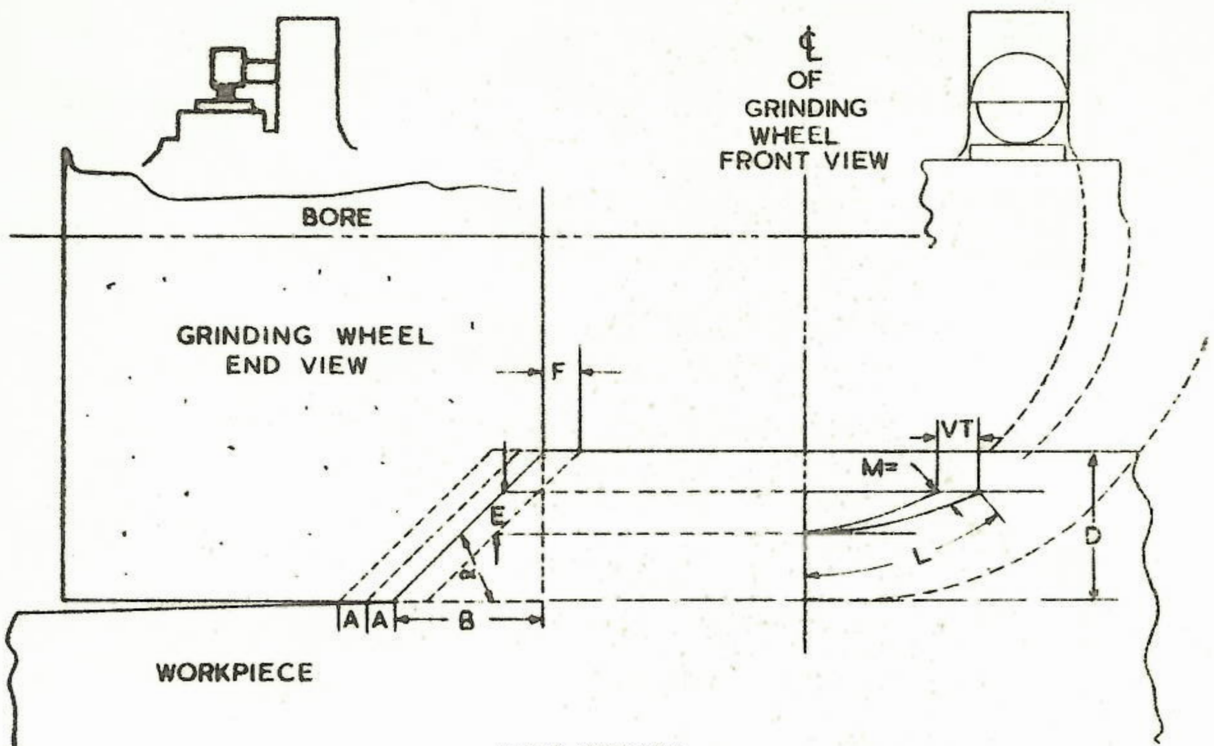
Summary

The purpose of the new grinding method is to enable a numerical appreciation of the grinding process to be made. From data gathered during practical tests, the characteristics of grinding wheel wear and the effect of changes in process conditions can be interpreted and the causes of failure and limitation in performance specified.

The comparative efficiency of different wheel and coolants may be numerically assessed and suggestions made for their improvement. Time standards may be set for the grinding process the comparative machinability of materials evaluated, and the effectiveness of different designs of the machine tool evaluated in terms of metal removal rate.

The work involved in a complete appreciation of the new method of grinding is at an academic and technical level which can be undertaken by the tool room machinist.

SCHEME OF THE LEADING EDGE SELF ADJUSTMENT
OF A SURFACE GRINDING WHEEL

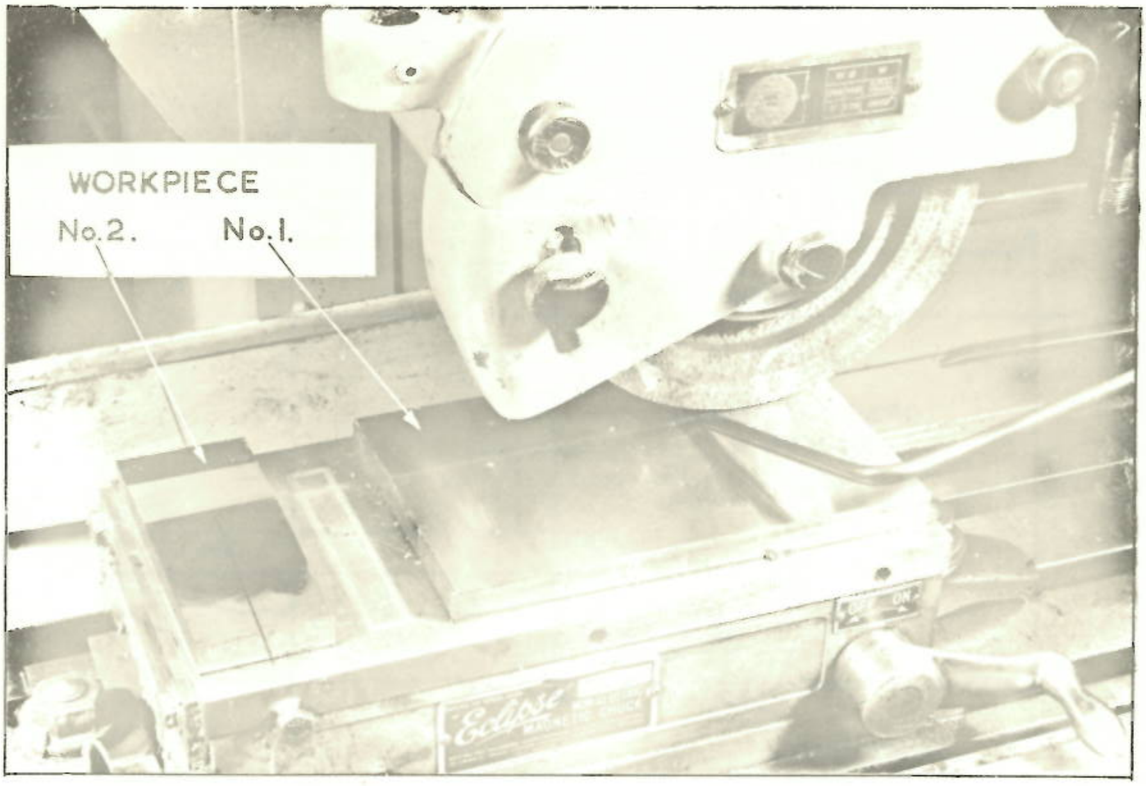


BASIC GEOMETRY

B = LOSS ON THE LEADING EDGE TO STABILISE ALPHA (α)
THE APPROACH ANGLE

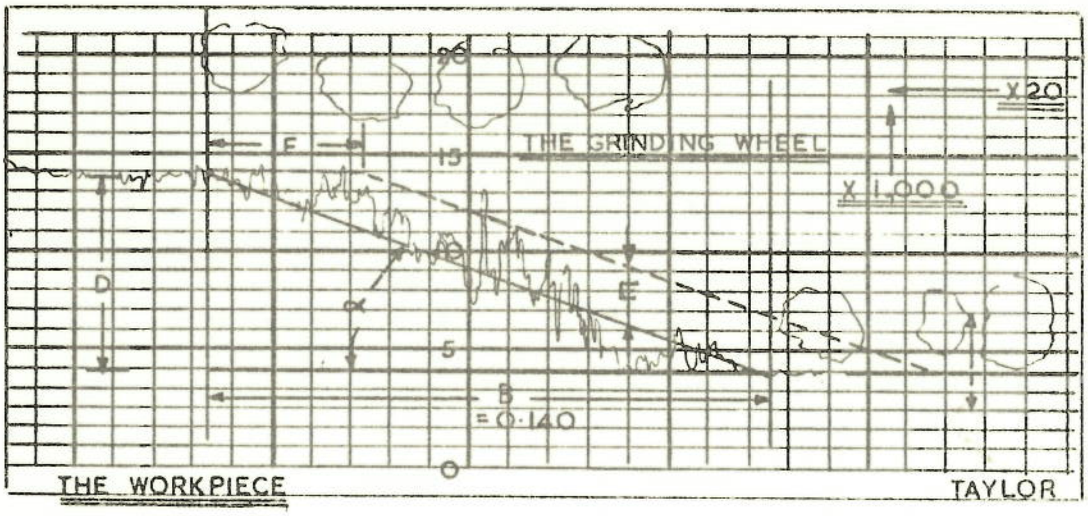
D = THE APPLIED DEPTH OF CUT. E = SELF ADJUSTED DEPTH OF CUT PER GRIT.
L = LENGTH OF WHEEL WORK ARC OF CONTACT = CHIP LENGTH (UNDERFORMED)
T = TIME IN MINUTES FOR A GRIT TO ROTATE L LENGTH OF ARC.
V = WORK TABLE SPEED IN INCHES PER MINUTE.
M = THE MAXIMUM POSSIBLE GRIT PENETRATION.
A = THE LOSS OF GRINDING WHEEL FACE FOR EACH UNIT
VOLUME OF METAL REMOVED FROM THE WORKPIECE.

Fig. 1



SHOWING MARKING BLUE METHOD OF MEASURING
GRINDING WHEEL FACE WIDTH

FIG 2



TALISURF TRACE OF LEADING EDGE OF THE GRINDING WHEEL

FIG. 3.

THE COMPARATIVE MACHINABILITY 3 ALLOY STEELS AND
GRINDING WHEEL POROSITY TEST

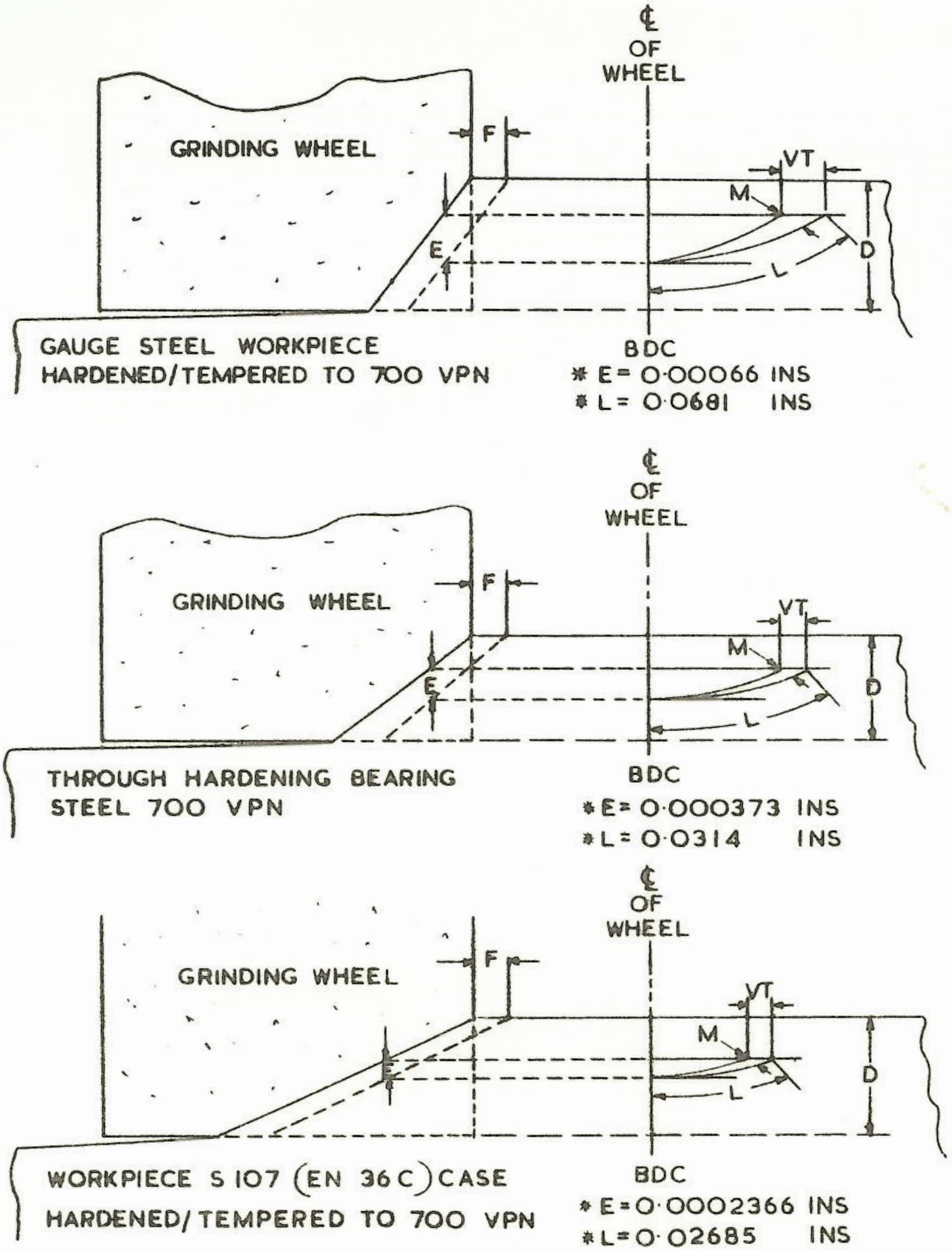


FIG 4.

SCHEME OF CHANGE IN PROPORTIONS OF THE APPROACH ANGLE
ALPHA WHEN THE DEPTH OF CUT (D) IS CHANGED

E.L.M.A. ALL REMAIN CONSTANT

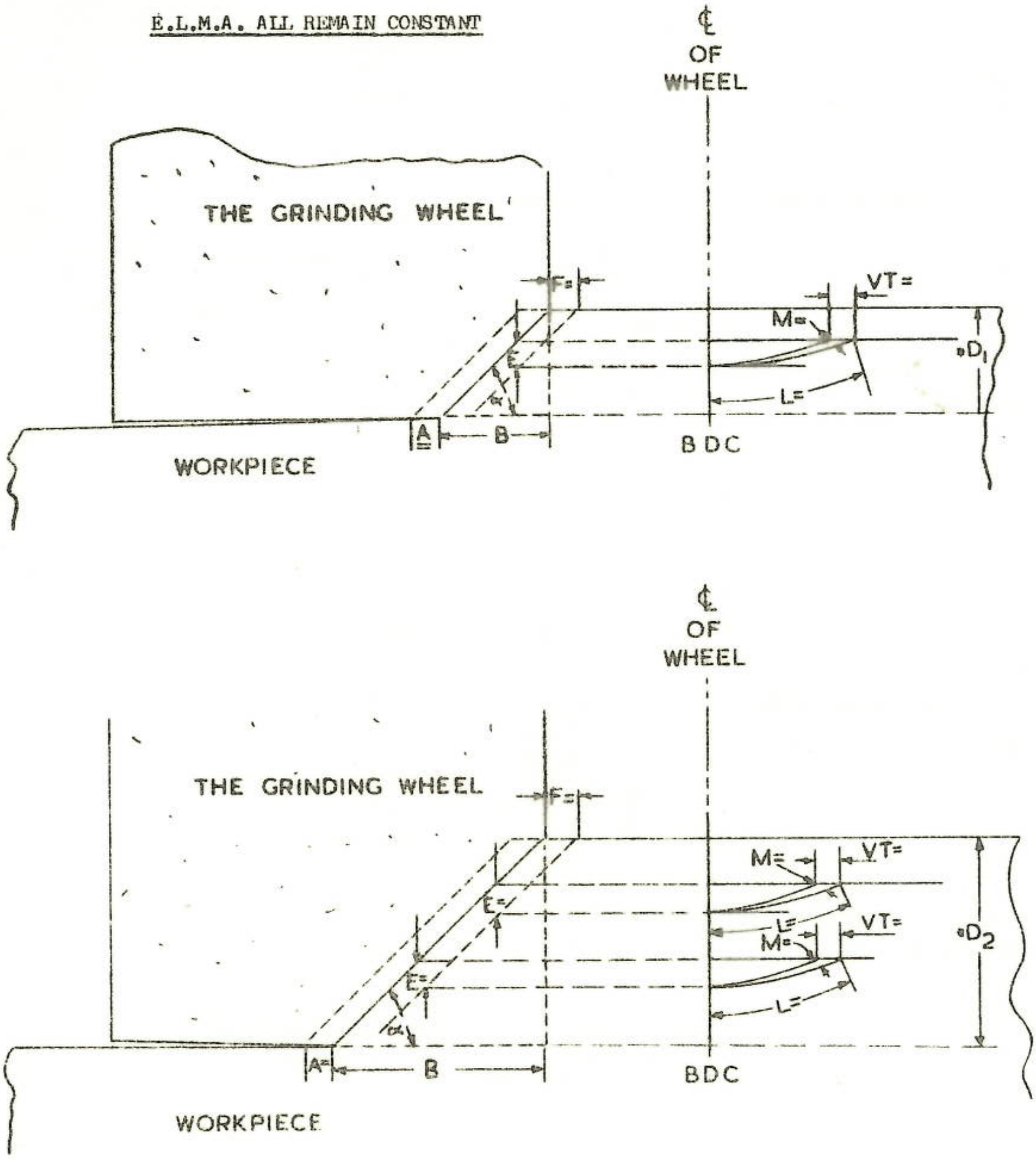
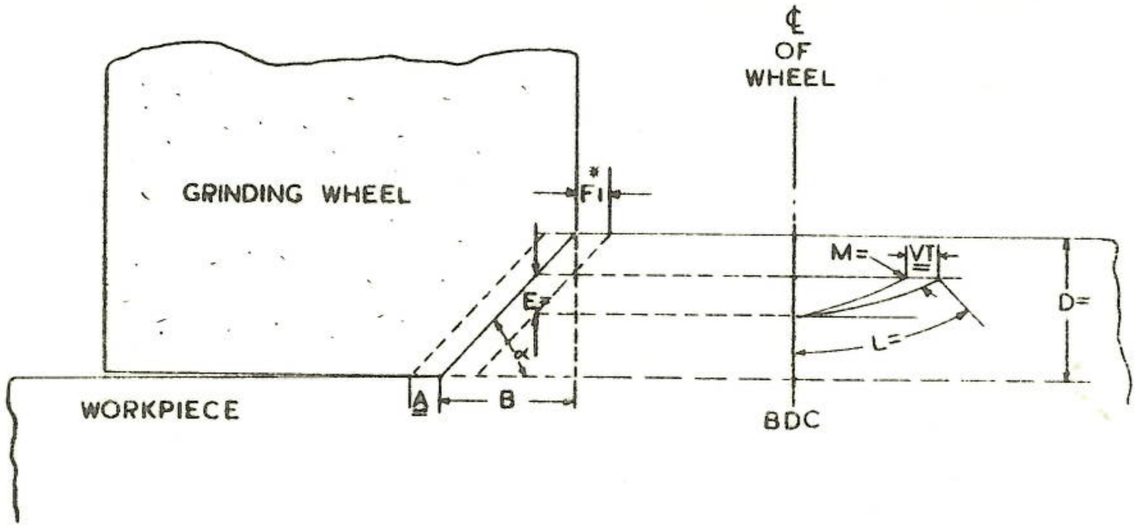
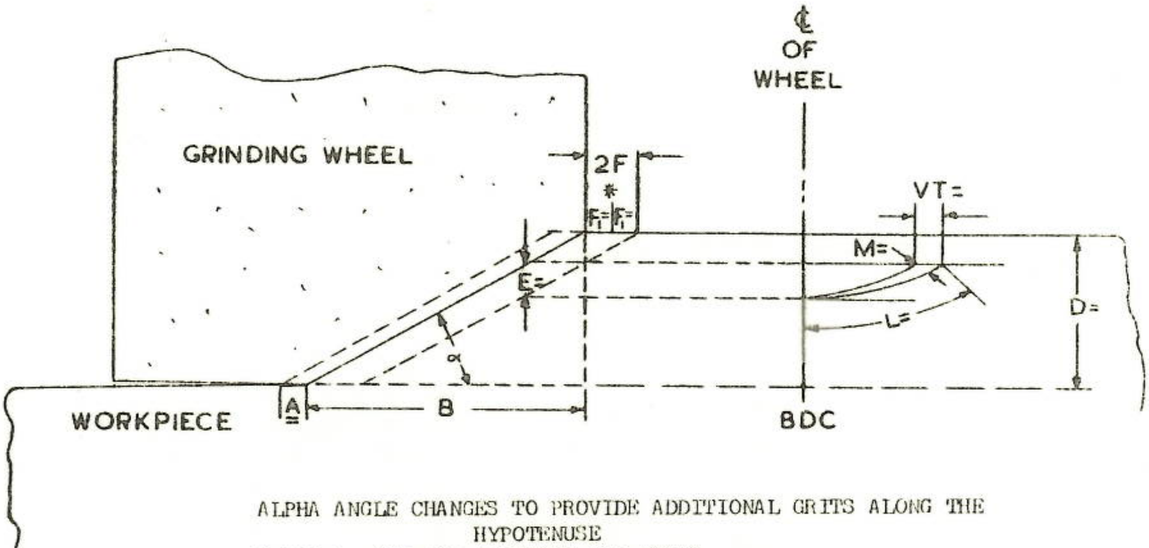


FIG. 5.

SCHEME OF THE CHANGE IN THE PROPORTIONS OF ALPHA ANGLE
AND THE VALUE OF ALPHA FOR A CHANGE IN CROSS FEED = *F

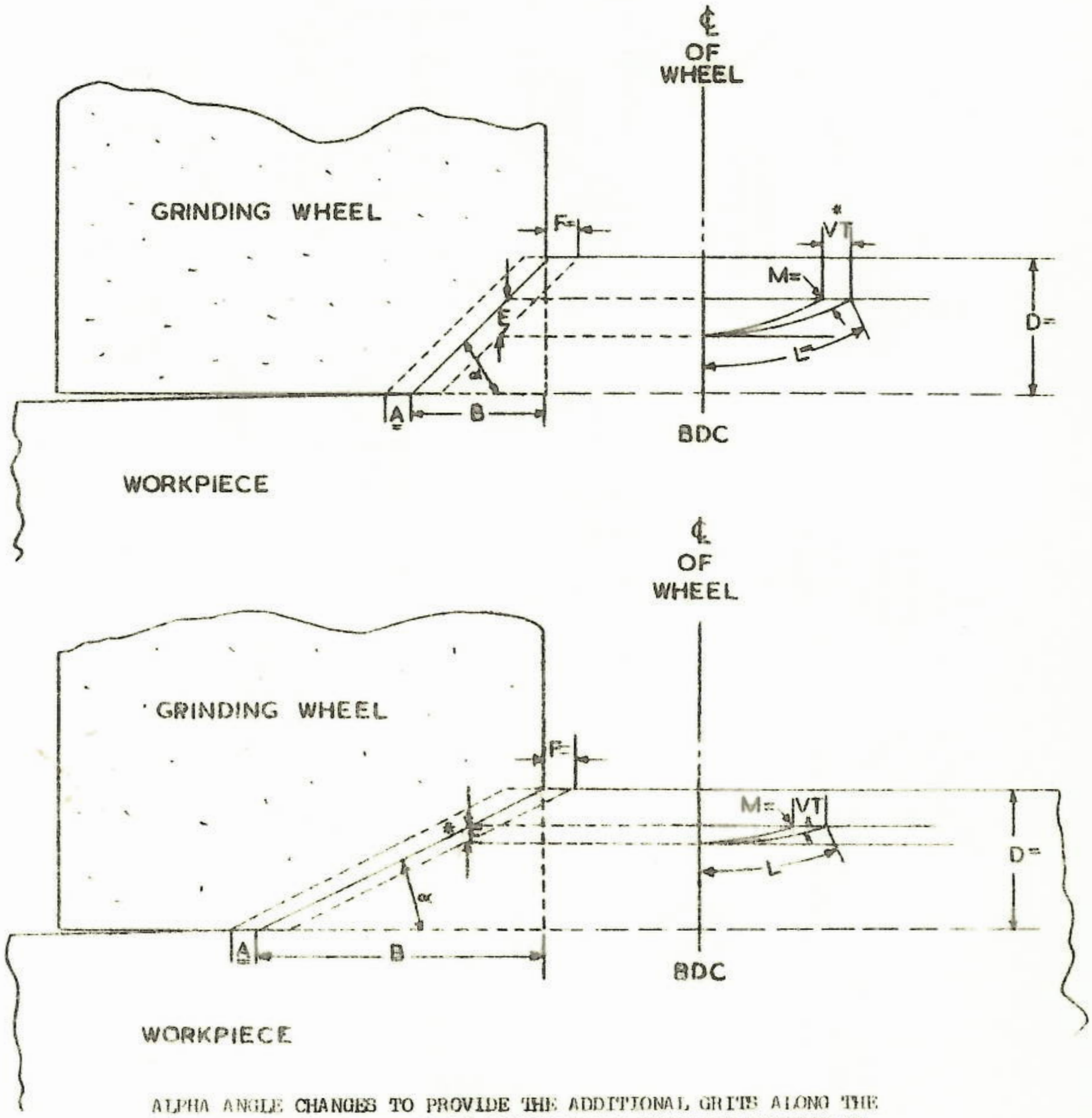




ALPHA ANGLE CHANGES TO PROVIDE ADDITIONAL GRITS ALONG THE HYPOTENUSE
E.L.M.A. ARE ALL CONSTANT AND EQUAL

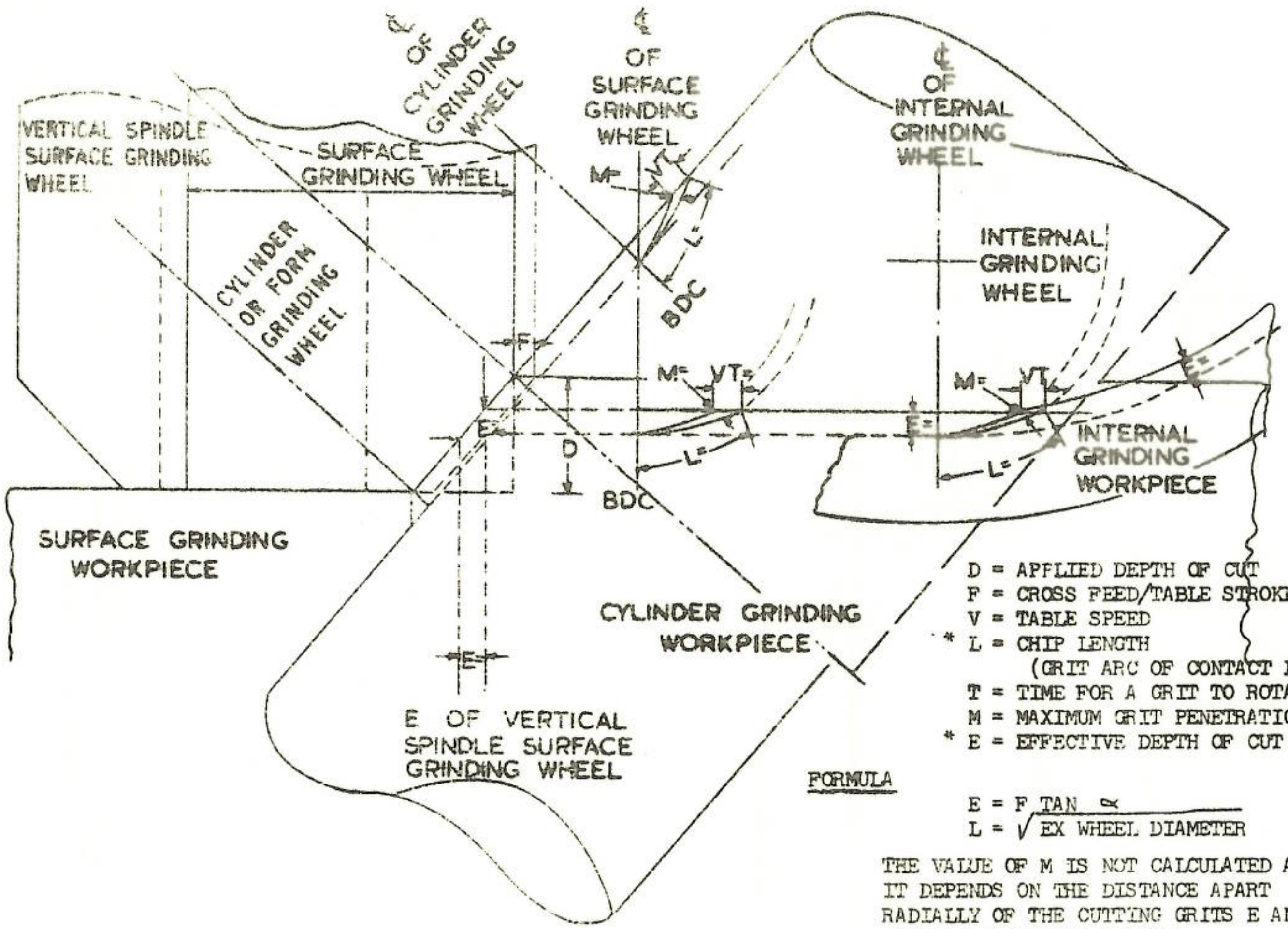
FIG 6.

SCHEME OF THE CHANGE IN THE PROPORTIONS OF ALPHA AND THE
VALUE OF ALPHA FOR A CHANGE IN TABLE SPEED *V



ALPHA ANGLE CHANGES TO PROVIDE THE ADDITIONAL GRITS ALONG THE HYPOTENUSE. E CHANGES TO REDUCE T AND MAKE THE PRODUCT OF V T PRODUCE A.L.M. CONSTANT.

FIG 7.



D = APPLIED DEPTH OF CUT
F = CROSS FEED/TABLE STROKE
V = TABLE SPEED
* L = CHIP LENGTH
(GRIT ARC OF CONTACT LENGTH)
T = TIME FOR A GRIT TO ROTATE L
M = MAXIMUM GRIT PENETRATION
* E = EFFECTIVE DEPTH OF CUT PER GRIT

<u>FORMULA</u>

$E = F \tan \alpha$

$L = \sqrt{EX \text{ WHEEL DIAMETER}}$

THE VALUE OF M IS NOT CALCULATED AS IT DEPENDS ON THE DISTANCE APART RADIALLY OF THE CUTTING GRITS E AND L ARE THE IMPORTANT VALUES

THE NUMERICAL EVALUATION OF MAXIMUM GRIT LOAD AND THE MECHANICS OF GRINDING WHEEL APPLICATION TO SURFACE CYLINDER INTERNAL AND FORM GRINDING

FIG 8.

GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: UN1. WA60. IV

Surface area ground sq. ins.	60	101	137	260			
Width of wheel lost in ins.	0.070	0.020	0.010	0.030			
Width of wheel left in ins.	0.930	0.910	0.900	0.870			
Surface finish micro ins CLA							

60 sq. in. = work done to stabilise approach angle α and wear in Zone B

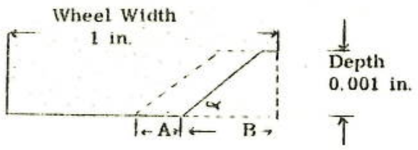
50 sq. in. the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point *	=	0.070 ins.
Loss on A per unit volume of stock removed	=	0.015 ins.
Total volume of stock removed for tests	=	0.260 cubic ins.
Loss of wheel in Zone B	=	0.00077 " "
Stock removed for loss in Zone B	=	0.060 " "
Loss of wheel in Zone A	=	0.00132 " "
Stock removed for loss in Zone A	=	0.2 " "
Ratio of work loss to wheel loss Zone B	=	78 to 1
Ratio of work loss to wheel loss Zone A	=	151 to 1
Number of unit volume lengths on A	=	57
Estimated life of wheel face in Zone B	=	0.060 cubic ins.
Estimated life of wheel face in Zone A	=	2.85 " "
Total estimated life = Zone A + Zone B	=	2.85 + 0.060 = 2.91 cubic ins.

Surface finish 10 micro ins. =

α = $0^{\circ}\ 49'$
E = 0.0006
L = 0.06460



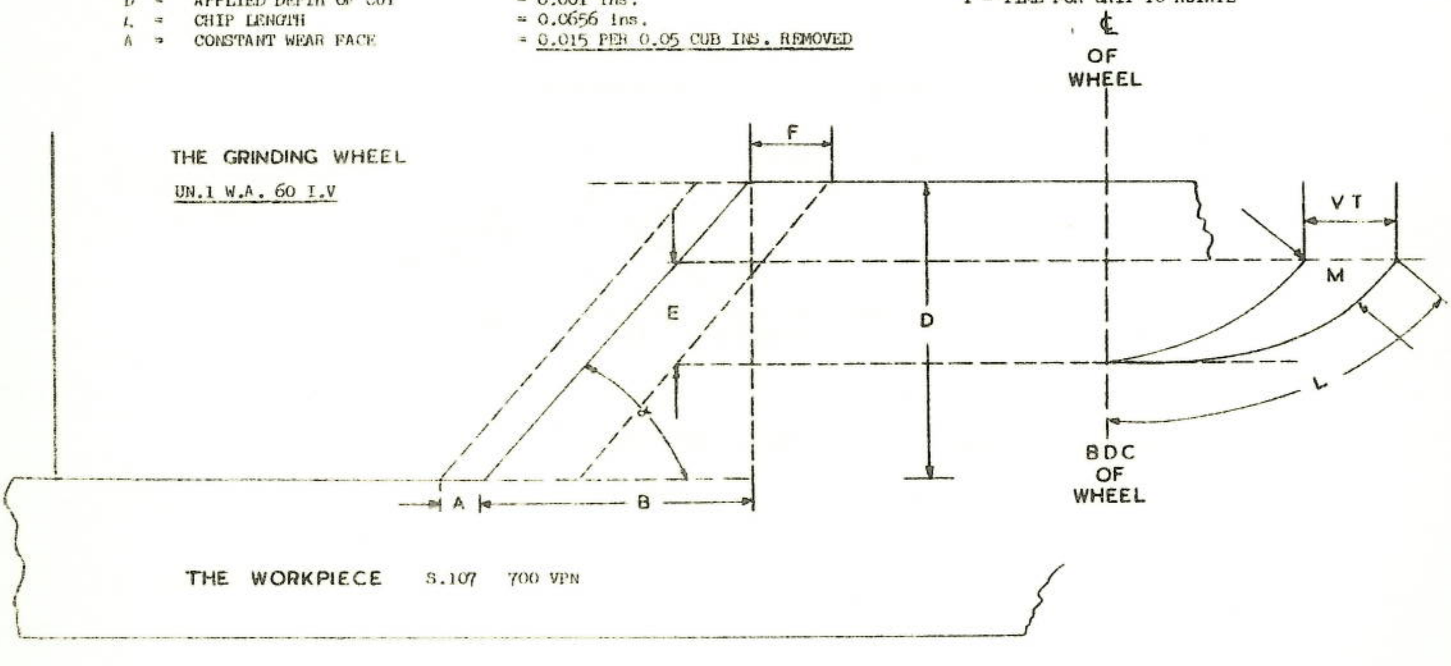
A = 0.015 B = 0.070 ins.
(Per 0.05 cub. ins. removed)

BASIC ELEMENTS OF GRINDING WHEEL SELF ADJUSTMENT AND WEAR

No. 1.A.

α = APPROACH ANGLE = $0^{\circ}\ 49'$
E = EFFECTIVE DEPTH OF CUT PER GRIT = 0.0006 ins *
D = APPLIED DEPTH OF CUT = 0.001 ins.
L = CHIP LENGTH = 0.0656 ins.
A = CONSTANT WEAR FACE = 0.015 PER 0.05 CUB INS. REMOVED

B = BASE OF APPROACH ANGLE 0.070 INS *
M = MAXIMUM GRIT PENETRATION
V = TABLE SPEED INS. SEC = 2.5 INS
T = TIME FOR GRIT TO ROTATE



GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: CARBORUNDUM 5-A-60-I-V50

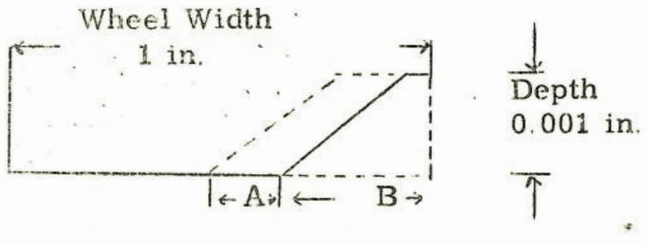
Surface area ground sq. ins.	43	173	290	428	567	700	825
Width of wheel lost in ins.	.055	.025	.015	.015	.020	.018	.022
Width of wheel left in ins.	.945	.920	.905	.890	.870	.852	.830
Surface finish micro ins CLA	4	4	4	4	4	4	4

* 43 = work done to stabilise approach angle α and wear in Zone B
+ 130 = the surface area at constant depth of 0.001 in taken as one unit volume of stock removed.

Summary of results

Loss on B to point *	=	.055 ins.
Loss on A per unit volume of stock removed	=	.020 ins.
Total volume of stock removed for tests	=	1.611 cubic ins.
Loss of wheel in Zone B	=	.0006 cubic ins.
Stock removed for loss in Zone B	=	.043 cubic ins.
Loss of wheel in Zone A	=	.00594 cubic ins.
Stock removed for loss in Zone A	=	1.568 cubic ins.
Ratio of work loss to wheel loss Zone B	=	70 to 1
Ratio of work loss to wheel loss Zone A	=	262 to 1
Number of unit volume lengths on A	=	44
Estimated life of wheel face in Zone B	=	0.043 cubic ins.
Estimated life of wheel face in Zone A	=	5.78 cubic ins.
Total estimated life = Zone A + Zone B	=	5.823 cubic ins.

Surface finish micro ins. = 4



A = .020 ins. B = .055 ins.

RESULTS SHEET NO. 2.

GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: UNIVERSAL W.A. 60. J.V.

Surface area ground sq ins.	24	122	262	367	507		
Width of wheel lost in ins.	0.070	0.030	0.030	0.030	0.020		
Width of wheel left in ins.	0.930	0.900	0.870	0.840	0.820		
Surface finish micro ins.CLA							

24 sq ins. = work done to stabilise approach angle α and wear in Zone B

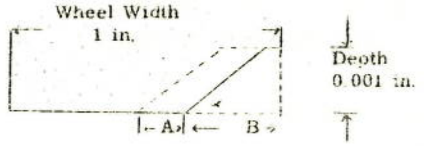
50 sq in. = the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point *	=	0.070 INS.
Loss on A per unit volume of stock removed	=	0.0116 INS
Total volume of stock removed for tests	=	0.507 CUB. INS.
Loss of wheel in Zone B	=	0.00077 CUB. INS.
Stock removed for loss in Zone B	=	0.024 CUB. INS.
Loss of wheel in Zone A	=	0.00242 CUB. INS.
Stock removed for loss in Zone A	=	0.477 CUB. INS
Ratio of work loss to wheel loss Zone B	=	31 to 1
Ratio of work loss to wheel loss Zone A	=	192 to 1
Number of unit volume lengths on A	=	70
Estimated life of wheel face in Zone B	=	0.024 CUB. INS.
Estimated life of wheel face in Zone A	=	3.5 CUB. INS.
Total estimated life = Zone A + Zone B	=	3.524 CUB. INS.

Surface finish micro ins. = 8

E = 0.0006
L = 0.0646
α = 0° 49'



A = 0.0116 B = 0.070
(Per 0.05 cub. ins. metal removed)

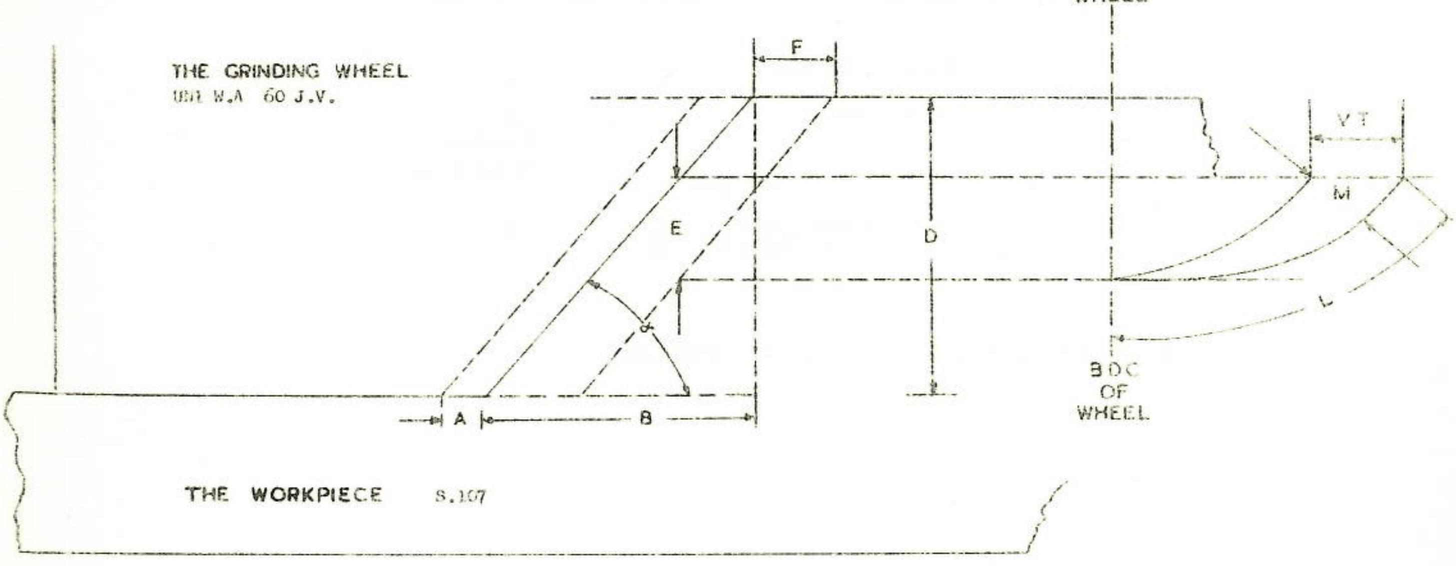
BASIC ELEMENTS OF GRINDING WHEEL SELF ADJUSTMENT AND WEAR

No. 2A

B = BASE OF APPROACH ANGLE = 0.070 INS
M = MAXIMUM GRIT PENETRATION
V = TABLE SPEED INS. SEC. 2.5 INS
T = TIME FOR GRIT TO ROTATE

α = APPROACH ANGLE = 0° 49'
E = EFFECTIVE DEPTH OF CUT PER GRIT = 0.0006 INS *
D = APPLIED DEPTH OF CUT = 0.001 INS
= CHIP LENGTH = 0.0646 INS
A = CONSTANT WEAR FACE * 0.0116 INS. PER 0.05 INS. REMOVED.

℄ OF WHEEL



RESULTS SHEET NO. 2A

GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: CARBORUNDUM 5A-60-J-V50

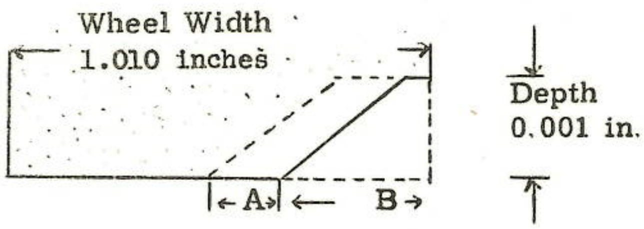
Surface area ground sq.ins.	63	151	242	352	456	549	659
Width of wheel lost in ins.	0.055	0.017	0.020	0.015	0.012	0.020	0.020
Width of wheel left in ins.	0.955	.938	.918	.903	.891	.871	.851
Surface finish micro ins.CLA	4	4	3	4	4	4	4

✱ 63 = work done to stabilise approach angle α and wear in Zone B
+ 103 = the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point ✱	= 0.055 ins.
Loss on A per unit volume of stock removed	= 0.017 ins.
Total volume of stock removed for tests	= 1.682 cubic ins.
Loss of wheel in Zone B	= 0.0006 cubic ins.
Stock removed for loss in Zone B	= 0.063 cubic ins.
Loss of wheel in Zone A	= 0.00704 cubic ins.
Stock removed for loss in Zone A	= 1.619 cubic ins.
Ratio of work loss to wheel loss Zone B	= 105 to 1
Ratio of work loss to wheel loss Zone A	= 230 to 1
Number of unit volume lengths on A	= 53
Estimated life of wheel face in Zone B	= 0.063 cubic ins.
Estimated life of wheel face in Zone A	= 5.457 cubic ins.
Total estimated life = Zone A + Zone B	= 5.457 + 0.063
	= 5.52 cubic ins.

Surface finish micro ins. = 4 CLA



A = 017 inches B = 055 inches

RESULTS SHEET NO. 3.

GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: 7.A-60-I5-VF8

Surface area ground sq. ins.	Start	105	140	175	210	245	280
Width of wheel lost in ins.	None	0.100	0.010	0.020	0.010	0.220	0.005
Width of wheel left in ins.	0.900	0.880	0.870	0.850	0.840	0.820	0.815
Surface finish micro ins.CLA							

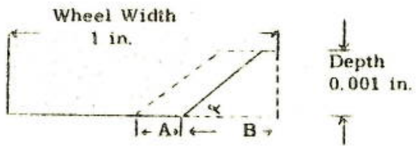
100 sq. in = work done to stabilise approach angle α and wear in Zone B
50 sq. in = the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point *	=	0.100 ins.
Loss on A per unit volume of stock removed	=	0.016 = 50 sq. ins.
Total volume of stock removed for tests	=	0.350 cub. ins
Loss of wheel in Zone B	=	0.0011 cub. ins.
Stock removed for loss in Zone B	=	0.105 cub. ins.
Loss of wheel in Zone A	=	0.00176 cub. ins.
Stock removed for loss in Zone A	=	0.245 cub. ins.
Ratio of work loss to wheel loss Zone B	=	95 to 1
Ratio of work loss to wheel loss Zone A	=	142 to 1
Number of unit volume lengths on A	=	= 53
Estimated life of wheel face in Zone B	=	0.105
Estimated life of wheel face in Zone A	=	0.05 x 53 = 2.62
Total estimated life = Zone A + Zone B	=	2.62 + 0.105 = 2.725

Surface finish 8 micro ins. =

E = .0004
L = .053
α = $0^{\circ}34$



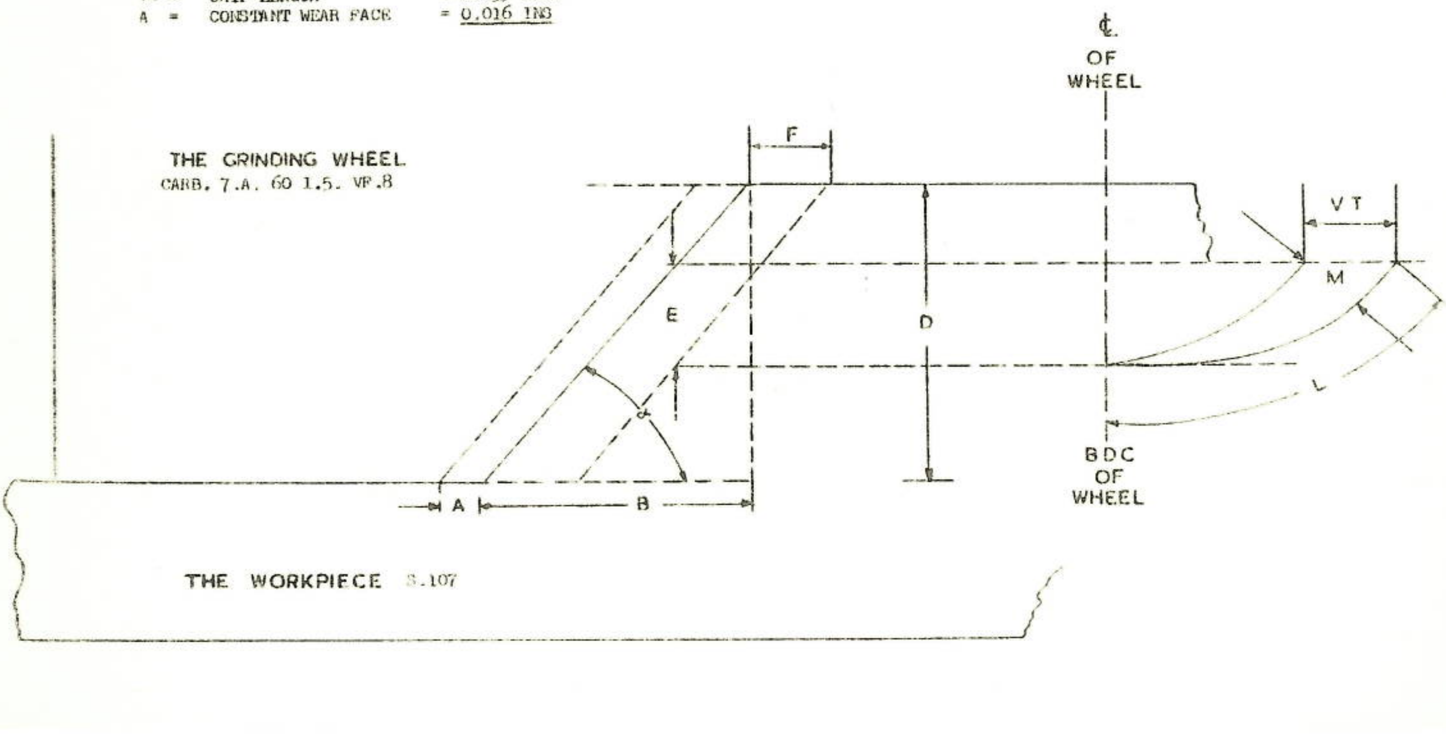
A = 0.016 ins. B = 0.100 ins.

No. 3.A

BASIC ELEMENTS OF GRINDING WHEEL SELF ADJUSTMENT AND WEAR

α = APPROACH ANGLE = 0° 34'
E = EFFECTIVE DEPTH OF CUT PER GRIT = 0.0004 INS
D = APPLIED DEPTH OF CUT = 0.001 INS.
L = CHIP LENGTH = 0.053 INS.
A = CONSTANT WEAR FACE = 0.016 INS

B = BASE OF APPROACH ANGLE = 0.100 INS
M = MAXIMUM GRIT PENETRATION
V = TABLE SPEED INS. SEC. = 2.5 INS
T = TIME FOR GRIT TO ROTATE



GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: Carborundum 7A 60 J5 VF8

Surface area ground sq. ins.	Start	* 50	82	114	146	162	
Width of wheel lost in ins.	None	0.100	0.005	0.015	0.010	0.005	
Width of wheel left in ins.	1.000	0.900	0.845	0.880	0.870	0.865	
Surface finish micro ins CLA							

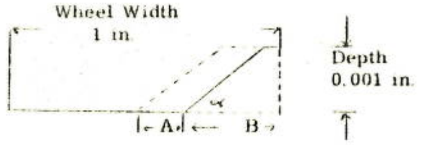
* 50 sq ins - work done to stabilise approach angle α and wear in Zone B
50 sq ins the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point *		0.100 ins
Loss on A per unit volume of stock removed		0.012 Ins
Total volume of stock removed for tests	=	0.162 cubic ins.
Loss of wheel in Zone B	=	0.0011 " "
Stock removed for loss in Zone B	=	0.050 " "
Loss of wheel in Zone A	=	0.00077 " "
Stock removed for loss in Zone A	=	0.112 " "
Ratio of work loss to wheel loss Zone B	=	40.6 to 1
Ratio of work loss to wheel loss Zone A	=	145 to, 1
Number of unit volume lengths on A	=	75 - 3 for x = 72
Estimated life of wheel face in Zone B	=	0.050 cubic ins.
Estimated life of wheel face in Zone A	=	72 x 3.6 = 3.6 cubic ins.
Total estimated life = Zone A + Zone B	=	0.050 + 3.6 = 3.65 cub. ins

Surface finish 10 micro ins. =

E = 0.0004
L = 0.053
α = 0° 34'



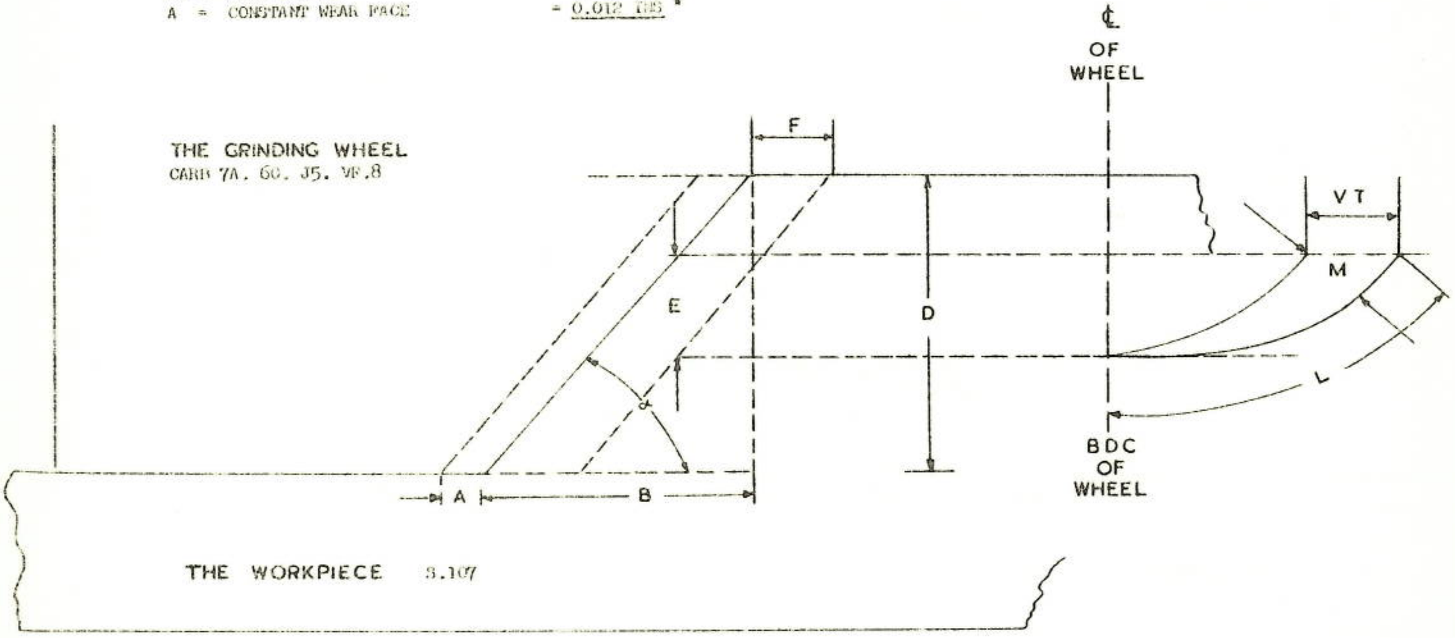
A = 0.012 ins. B = 0.100 ins.
(0.05 cub. ins)

BASIC ELEMENTS OF GRINDING WHEEL SELF ADJUSTMENT AND WEAR

No. 4A

α = APPROACH ANGLE = 0° 34'
E = EFFECTIVE DEPTH OF CUT PER GRIT = 0.004 INS *
D = APPLIED DEPTH OF CUT = 0.001 INS
L = CHIP LENGTH = 0.053 INS
A = CONSTANT WEAR FACE = 0.012 INS *

B = BASE OF APPROACH ANGLE = 0.100 INS
M = MAXIMUM GRIT PENETRATION
V = TABLE SPEED INS. SEC. = 2.5 INS
T = TIME FOR GRIT TO ROTATE



GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: A54 J5 - V30

Surface area ground sq ins.	88	184	289	390	456		
Width of wheel lost in ins.	0.140	0.020	0.010	0.010	0.010		
Width of wheel left in ins.	0.860	0.840	0.830	0.820	0.810		
Surface finish micro ins CLA	741	725	741	725	713		

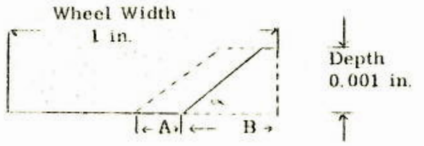
140 sq in. = work done to stabilise approach angle α and wear in Zone B
50 sq in. the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point *	=	0.140 INS.
Loss on A per unit volume of stock removed	=	0.007 INS
Total volume of stock removed for tests	=	0.456 CUBIC INS.
Loss of wheel in Zone B	=	0.00154 " "
Stock removed for loss in Zone B	=	0.088 " "
Loss of wheel in Zone A	=	0.0011 " "
Stock removed for loss in Zone A	=	0.368 " "
Ratio of work loss to wheel loss Zone B	=	57 to 1
Ratio of work loss to wheel loss Zone A	=	334 to 1
Number of unit volume lengths on A	=	114
Estimated life of wheel face in Zone B	=	0.088 CUBIC INS.
Estimated life of wheel face in Zone A	=	5.7 " "
Total estimated life = Zone A + Zone B	=	5.788 " "

Surface finish 10 micro ins. =

$E = 0.0003''$
$L = 0.0456''$
$\alpha = 0^\circ\ 24'$



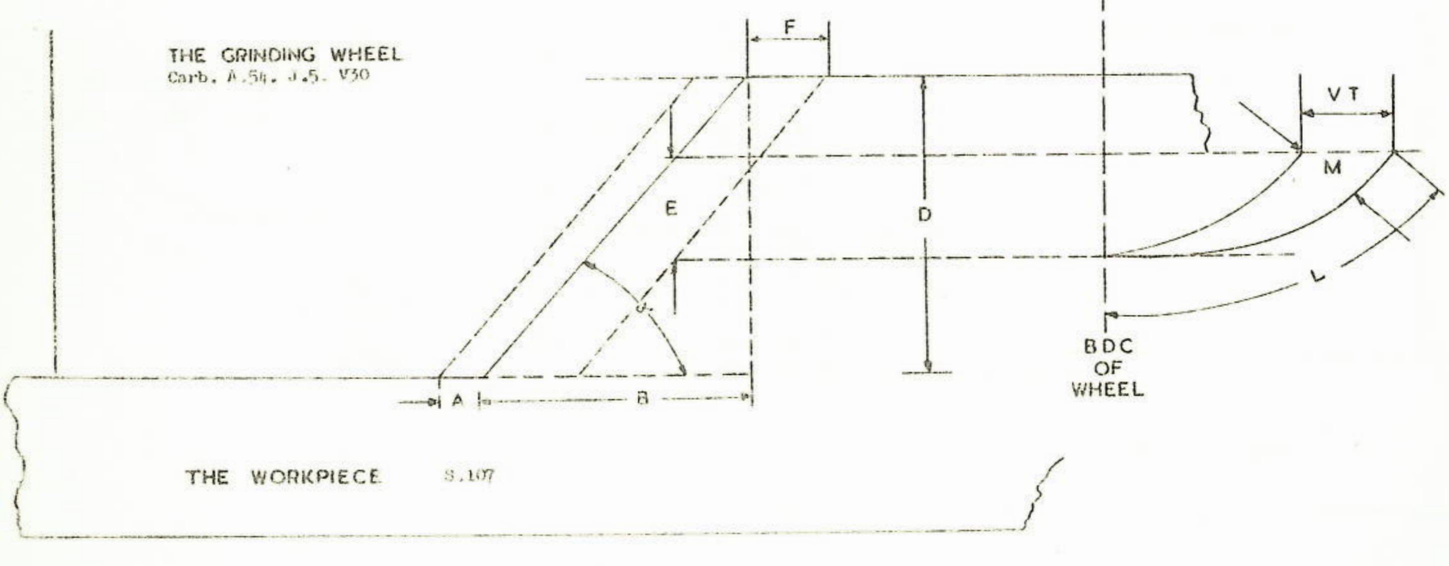
* A = 0.007 Ins B = 0.140 Ins
(per 0.05 cub. Ins)

BASIC ELEMENTS OF GRINDING WHEEL SELF ADJUSTMENT AND WEAR

No. 5A

α = APPROACH ANGLE = $0^\circ\ 24'$
E = EFFECTIVE DEPTH OF CUT PER GRIT = 0.0003 INS
D = APPLIED DEPTH OF CUT = 0.001 INS
= CHIP LENGTH = 0.045 INS
A = CONSTANT WEAR FACE * = 0.007 INS

B = BASE OF APPROACH ANGLE = 0.140 INS
M = MAXIMUM GRIT PENETRATION
V = TABLE SPEED INS. SEC. = 2.5 INS
T = TIME FOR GRIT TO ROTATE



RESULTS SHEET NO. 6

GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: A 54-J5-V30

Surface area ground sq. ins.	140	27	319	398	498		
Width of wheel lost in ins.	0.140	000	0.025	0.015	0.025		
Width of wheel left in ins.	0.860	0.860	0.835	0.820	0.795		
Surface finish micro ins. CLA							

140 sq in - work done to stabilise approach angle ∝ and wear in Zone B

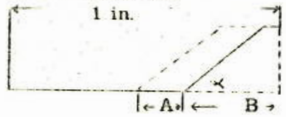
50 sq in the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point *	=	0.140 ins.
Loss on A per unit volume of stock removed	=	0.010 ins.
Total volume of stock removed for tests	=	0.498 cub.ins.
Loss of wheel in Zone B	=	0.00154 cub.ins.
Stock removed for loss in Zone B	=	0.140 cub.ins.
Loss of wheel in Zone A	=	0.00143 cub.ins.
Stock removed for loss in Zone A	=	0.358 cub.ins.
Ratio of work loss to wheel loss Zone B	=	91 to 1
Ratio of work loss to wheel loss Zone A	=	225 to 1
Number of unit volume lengths on A	=	80
Estimated life of wheel face in Zone B	=	0.140 cub.ins.
Estimated life of wheel face in Zone A	=	4.00 cub.ins.
Total estimated life = Zone A + Zone B	=	4.00+140 = 4.140 cub.ins.

Surface finish 14 micro ins. =

E = 0003
L = .0456
∝ = 0°24'



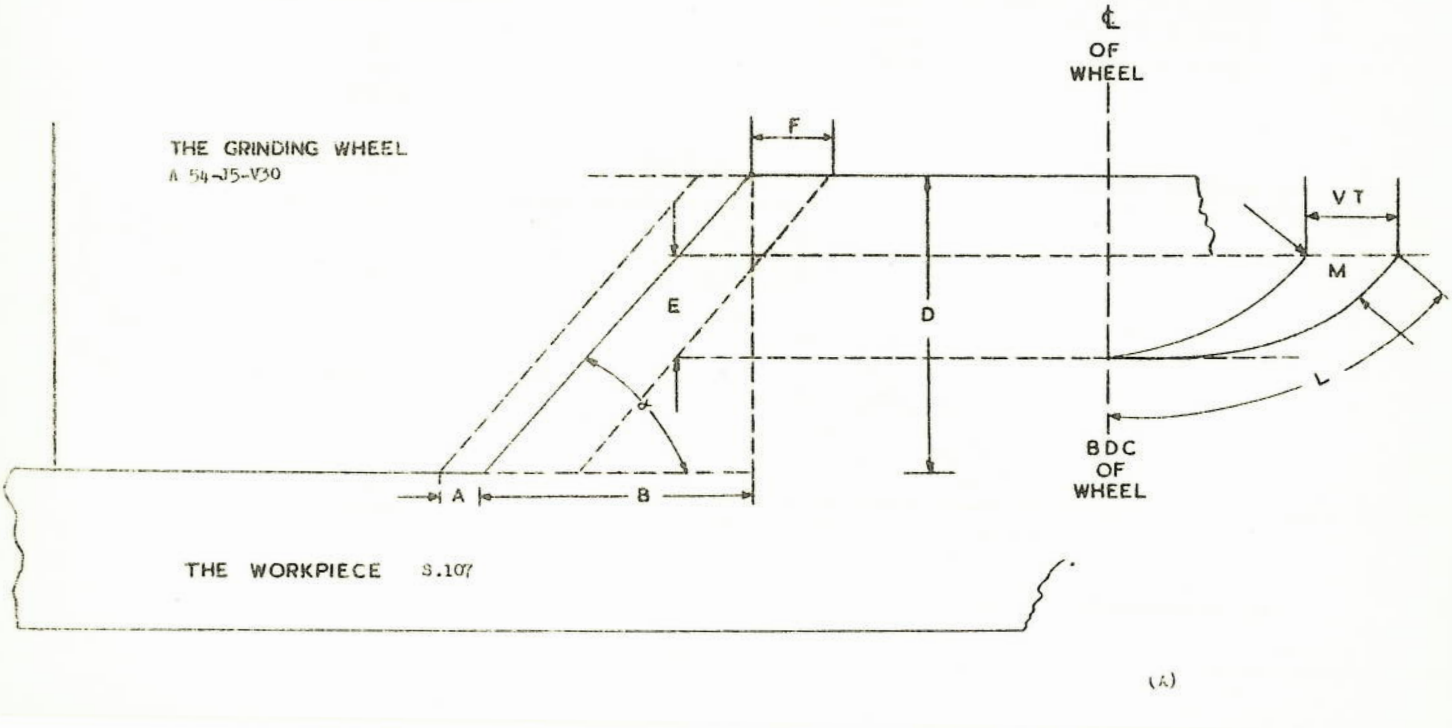
A = 0.010 ins. B = 0.140 ins.
= (per 0.05 cu. ins.)

No. 6.A

BASIC ELEMENTS OF GRINDING WHEEL ADJUSTMENT AND WEAR

∝ = APPROACH ANGLE = 0°24'
E = EFFECTIVE DEPTH OF CUT PER GRIT = 0.0003 ins.
D = APPLIED DEPTH OF CUT PER GRIT = 0.001 ins.
L = CHIP LENGTH = 0.045 ins.
A = CONSTANT WEAR FACE = 0.010 ins.

B = BASE OF APPROACH ANGLE .140 ins.
M = MAXIMUM GRIT PENETRATION
V = TABLE SPEED INS. SEC. = 2.5 ins.
T = TIME FOR GRIT TO ROTATE



(A)

GRINDING WHEEL SELECTION TEST

WHEEL SPECIFICATION: Carb. 7.D.A. 60 1.5. VF.BLU

Surface area ground sq ins.	Start	72	750	1500	2250	3000	3750
Width of wheel lost in ins.	None	0.070	0.030	0.030	0.030	0.030	0.040
Width of wheel left in ins.	1.000	0.930	0.900	0.870	0.840	0.810	0.770
Surface finish micro ins.CLA	-	10 to 8	7	7	7	7	7

70 sq ins = work done to stabilise approach angle α and wear in Zone B

750 sq ins = the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

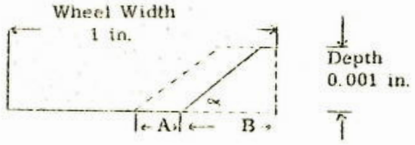
Manchester Oil Refinery. Dolphin No. 1 Oil Coolant

Summary of results

Loss on B to point *	=	0.070 INS
Loss on A per unit volume of stock removed	=	0.032 INS
Total volume of stock removed for tests	=	3.750 CUB. INS
Loss of wheel in Zone B	=	0. 00077 " "
Stock removed for loss in Zone B	=	0.072 " "
Loss of wheel in Zone A	=	0.00352 " "
Stock removed for loss in Zone A	=	3.678 " "
Ratio of work loss to wheel loss Zone B	=	100 to 1 approx
Ratio of work loss to wheel loss Zone A	=	1000 to 1 approx.
Number of unit volume lengths on A	=	30
Estimated life of wheel face in Zone B	=	0.072 CUB. INS
Estimated life of wheel face in Zone A	=	(30 - 2) x .750
Total estimated life = Zone A + Zone B	=	23.572 CUB. INS.

Surface finish micro ins. = 7

E = 0.00058
L = 0.0634
α = 0° 48'



A = 0.032 ins. B = 070 ins
(per 0.750 cub. ins)

No 7 A

BASIC ELEMENTS OF GRINDING WHEEL SELF ADJUSTMENT AND WEAR

α = APPROACH ANGLE = 0° 48'
E = EFFECTIVE DEPTH OF CUT PER GRIT = 0.00058 INS
D = APPLIED DEPTH OF CUT = 0.001 INS
= CHIP LENGTH = 0.0634 INS
A = CONSTANT WEAR FACE = 0.032 INS PER 750 SQ.IN GROUND

B = BASE OF APPROACH ANGLE 0.070 INS
M = MAXIMUM GRIT PENETRATION
V = TABLE SPEED INS. SEC. 2.5 INS
T = TIME FOR GRIT TO ROTATE